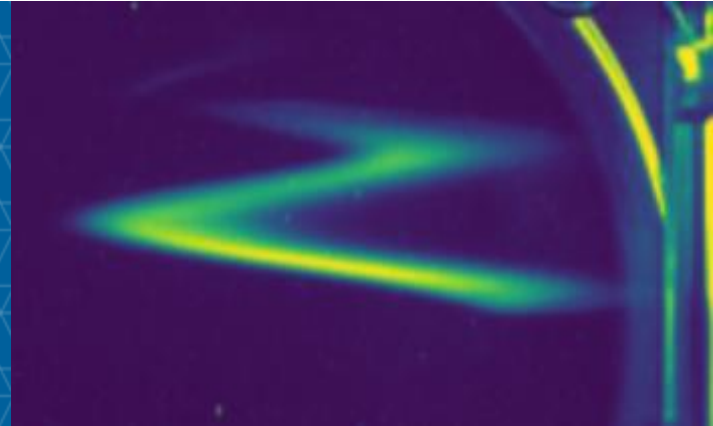


ENERGY RECOVERY IN BEAM-DRIVEN WAKEFIELD ACCELERATORS



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INTRODUCTION & MOTIVATION

E.M. pulse formation in slow-wave structures

- Wakefield generation in slow-wave structures yields pulse duration given by

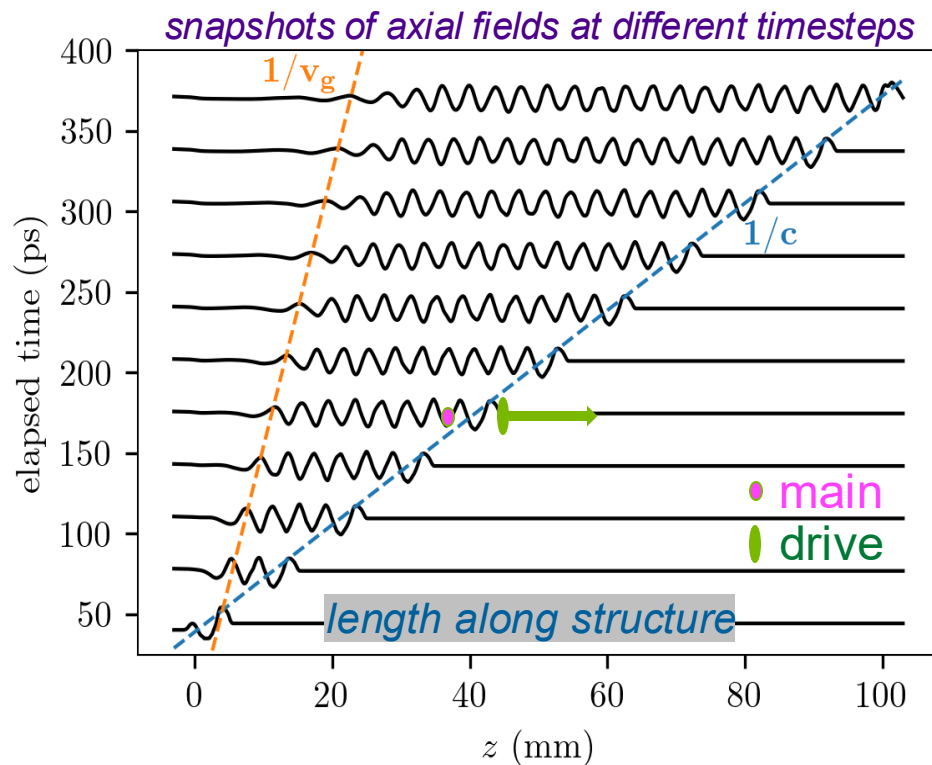
e.m. pulse duration $\tau = \ell \left(v_g^{-1} - c^{-1} \right)$

length of structure ℓ

group velocity of excited mode v_g

speed of light c

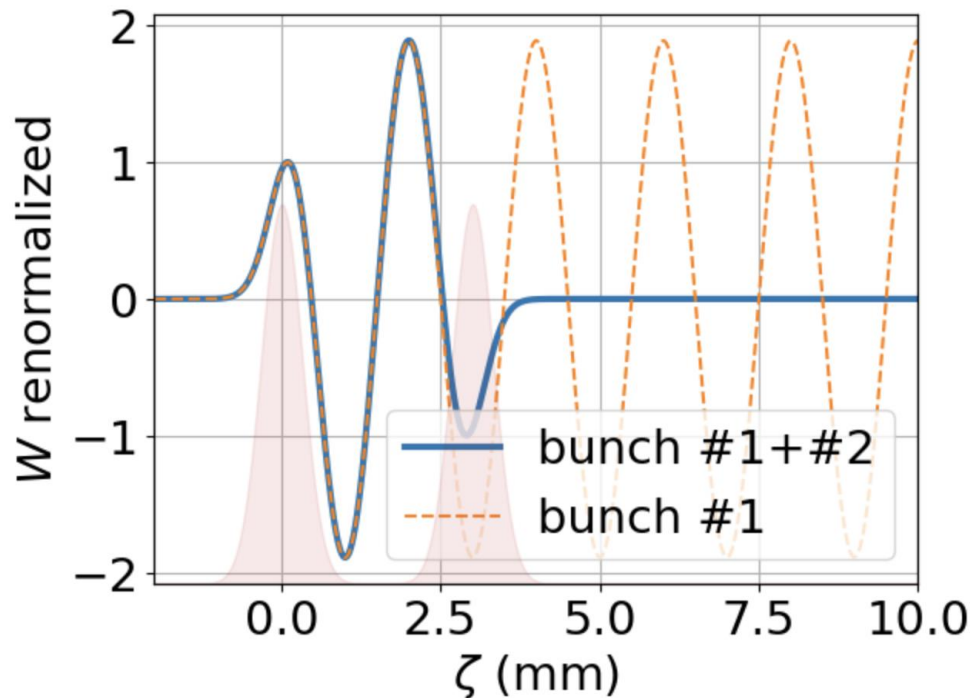
- Resulting in deposited energy proportional to the structure length
- Only the first accelerating bucket(s) are usually used for acceleration



CONTROL OF THE E.M. PULSE

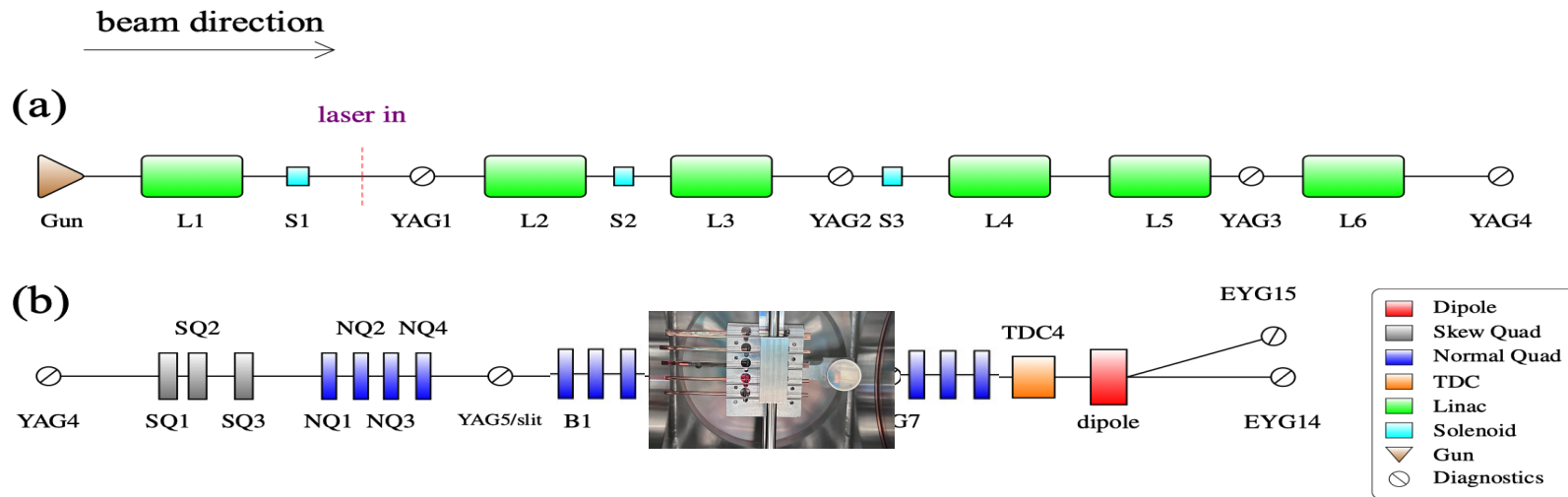
Use of a “loading” bunch

- Use two bunches to control the wakefield:
 - Drive bunch
 - Loading bunch
- The main (to be accelerated) bunch is flanked by the drive and loading bunches
- If the bunches are identical and separated by $\lambda(n+1/2)$ [where λ is the fundamental-mode wavelength]
- *Suppression is perfect*



EXPERIMENTAL SETUP

Experiment at the Argonne Wakefield Accelerator

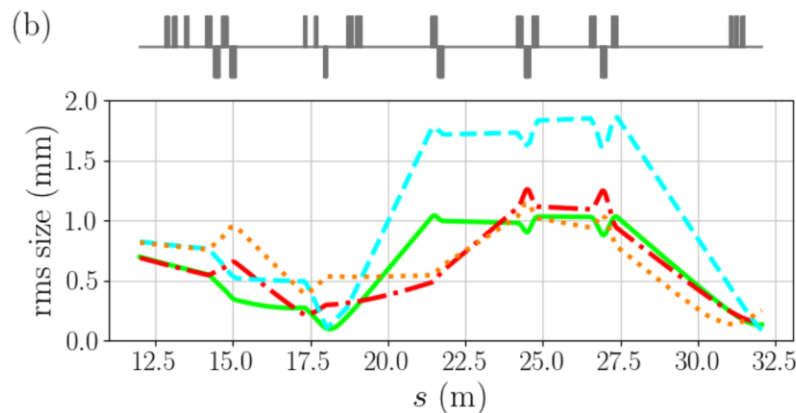
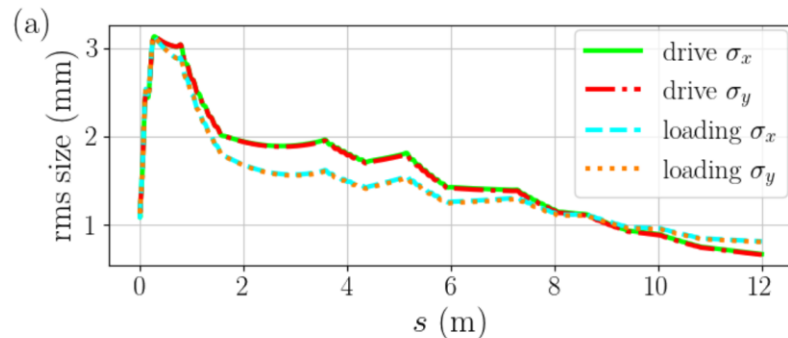
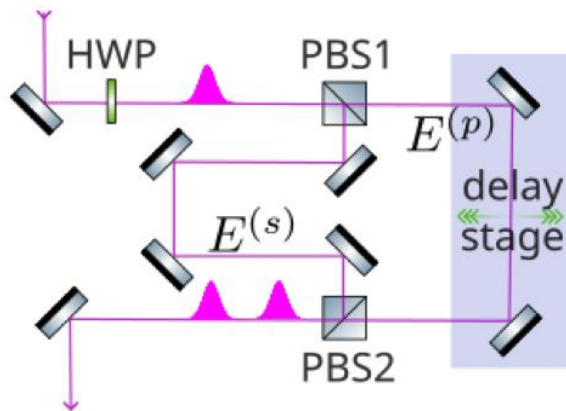


- 1-5 nC bunches (two bunches with controllable relative intensity/separation)
- Measure single-shot LPS for various delays
- Detect THz radiation and measure its duration (autocorrelation)

DUAL-BUNCH GENERATION & TRANSPORT (I)

Generation & beam dynamics

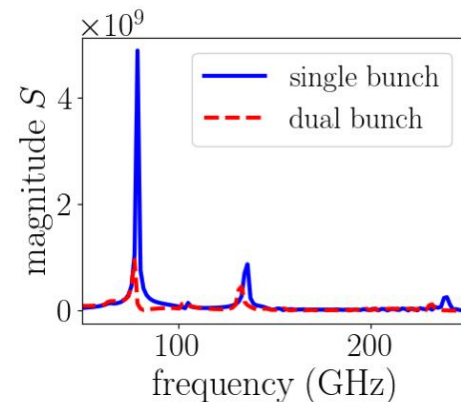
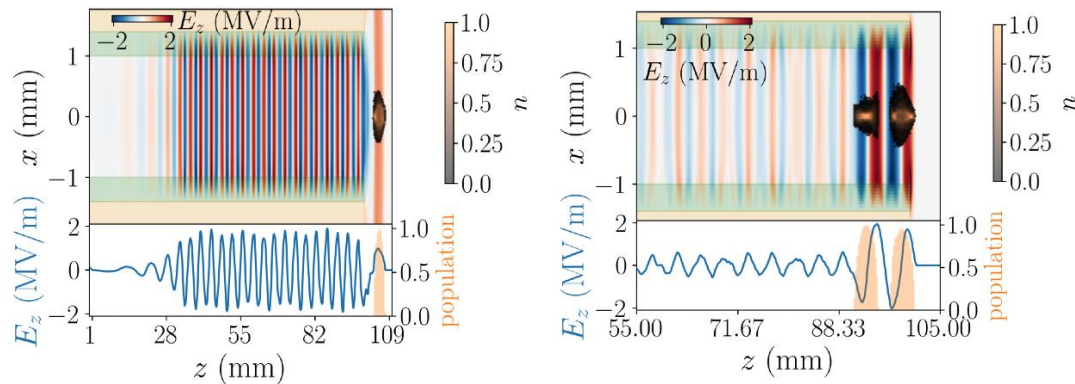
- Two-bunch ensemble produced from optical generation of two UV pulses
- Beam dynamics optimized to ensure two-bunch separated by $\sim 3\lambda$ are optimally focused in the structure



SUPPRESSION OF WAKE IMPERFECT

PIC simulations w/ WARP-X

- Stat-to-end simulation of dual bunch dynamics in OPAL-t
- Passed to WARP-X
- Results indicate:
 - Imperfect suppression of wakefield
 - Significant (>80%) reduction of radiated energy in the fundamental mod.
- Enough experimental control knobs to optimize cancellation (quadrupole small delay scan, etc...)

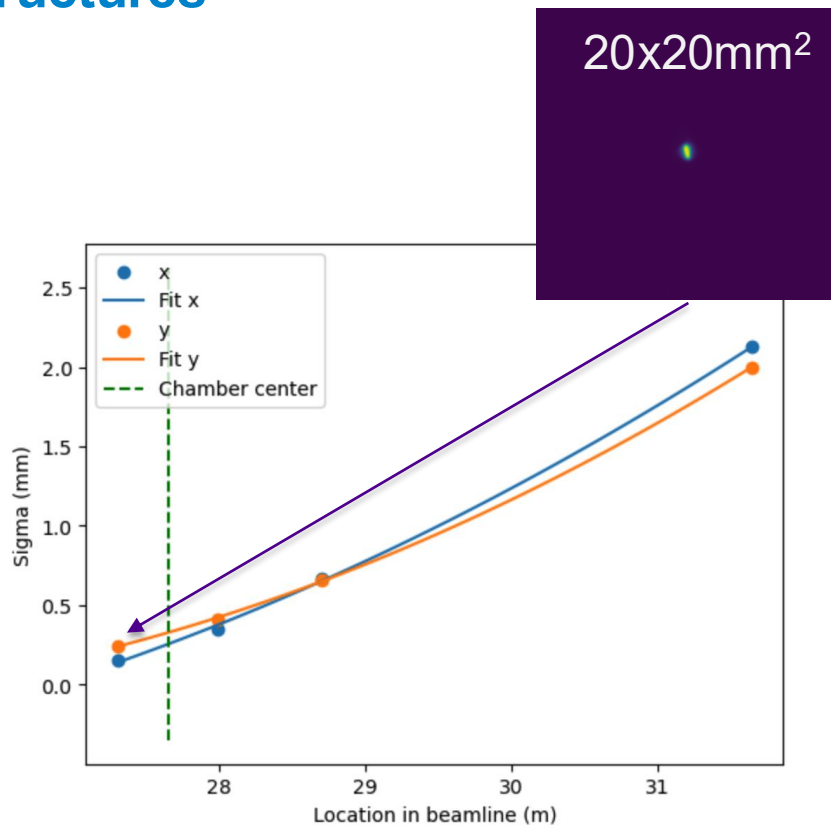
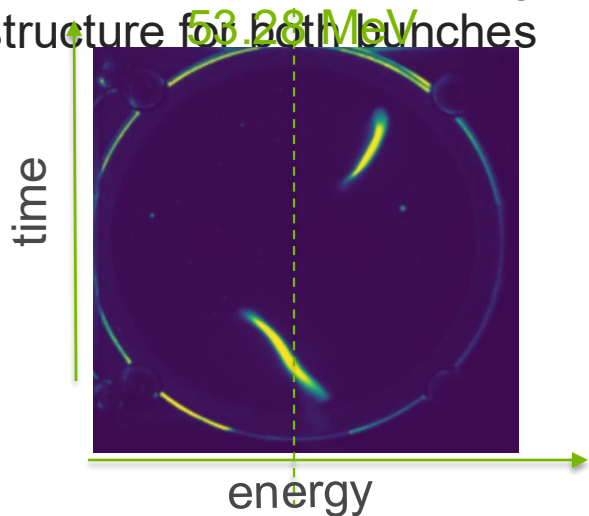


DUAL-BUNCH GENERATION & TRANSPORT (II)

E.M. pulse formation in slow-wave structures

- Generated/characterized dual-bunch system:

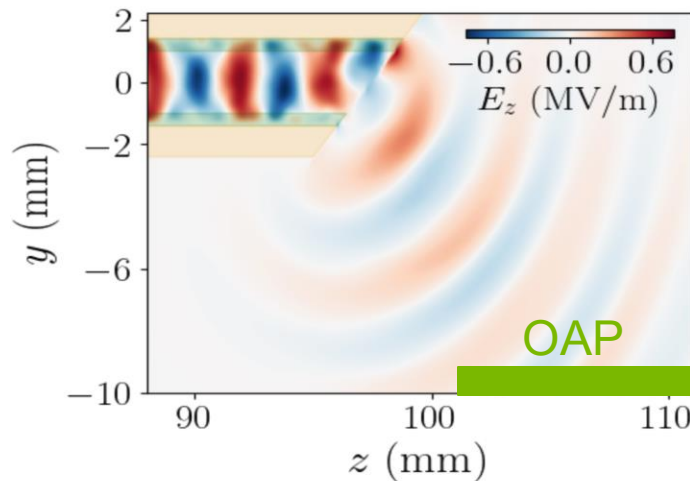
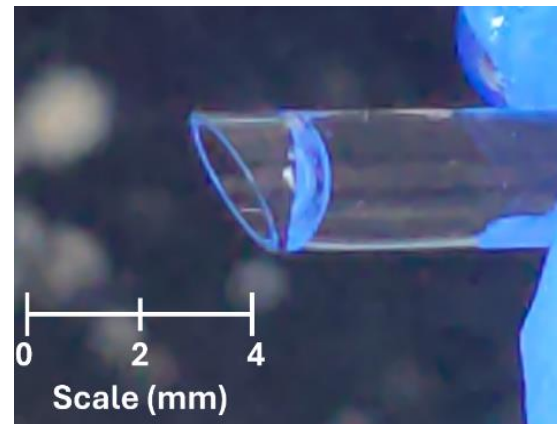
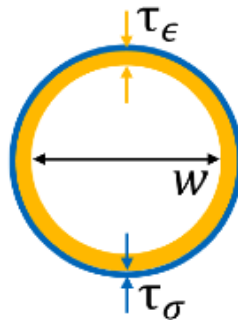
- average energy is ~ 53.3 MeV
- $>80\%$ transmission through structure for both bunches



STRUCTURE CHOICE

dielectric structure

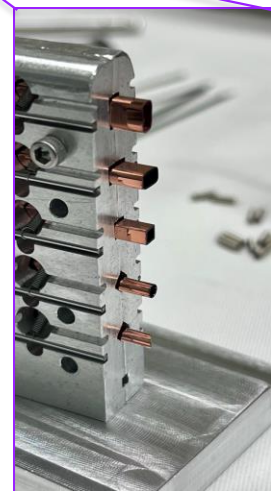
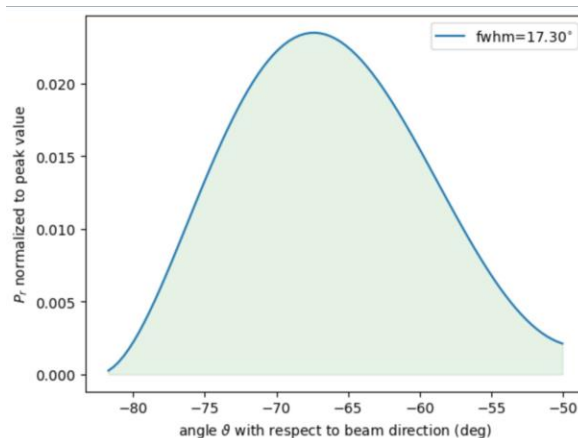
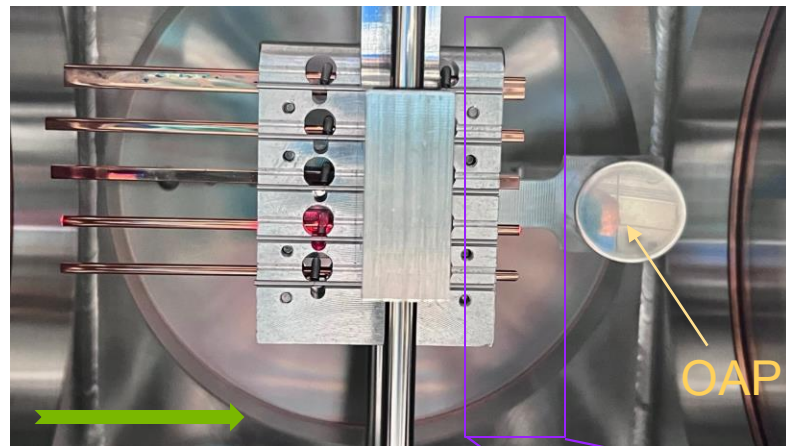
- Focus on cylindrical structures
- Used off-the shelf structures from VITROCON prepared at AWA/Euclid/NIU (cut + copper-layer deposition); fundamental mode @ $\lambda=2.09$ mm ($w=2$ mm, $\tau_\epsilon \sim 0.2$ mm)
- Vlasov antenna:
 - Oblique cut optimized for off-axis collection of sub-THz radiation
 - Avoid (ideally) overlap with transition radiation from in-line mirror



EXPERIMENTAL SETUP

dielectric structure

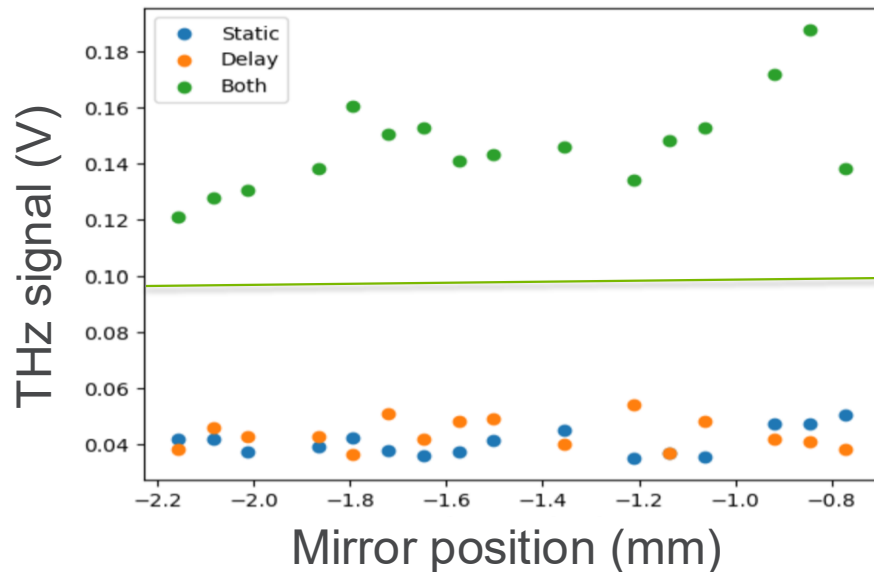
- Several structures are available and can be inserted in the beam path
- One of the structures has an oblique cut optimized for the radiation to hit an OAP
- The OAP-collimated pulse is directed outside of the UHV chamber through a sapphire optical port.



EXPERIMENTS

Beamtime in September

- Detected radiation
- Measured interaction of drive and witness bunches



SUMMARY

- A method to reducing the e.m. pulse produced in beam driven SWFA is suggested
- Experiment in progress at AWA:
 - Focuses on a simple two-bunch system: driver and loading bunches
 - Employs sub-THz dielectric-line waveguide ($\lambda=2.09$ mm fundamental mode)
- Pending on successful results next step include:
 - Addition of third (low charge) main bunch to demonstrate acceleration and sample the wakefield
 - Investigation of compensation beyond ideal conditions
- Open question:
 - Possible use of accelerated drive bunch
 - Control of wake beyond fundamental mode